NAIC-ID(RS)T-0375-95

NATIONAL AIR INTELLIGENCE CENTER

COMPUTER AIDED DESIGN FOR AIRCRAFT TOOLING
COORDINATION SYSTEM

by

Liu Liming, She Gongfan, Liu Tao

**Approved for public release:
distribution unlimited**

HUMAN TRANSLATION

NAIC-ID(RS)T-0375-95 4 December 1995

MICROFICHE NR: 95C000744

COMPUTER AIDED DESIGN FOR AIRCRAFT TOOLING COORDINATION SYSTEM

By: Liu Liming, She Gongfan, Liu Tao

English pages: 15

Source: Hangkong Xuebao, Vol. 15, Nr. 10, October 1994;
pp. 1230-1235

Country of origin: China
Translated by: SCITRAN
F33657-84-D-0165
Requester: NAIC/TATV/Beverly Brown
Approved for public release: distribution unlimited.

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

Accesion For	
NTIS CRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and / or Special
A-1	

Traditional aircraft tooling coordination design begins from the overall coordination plan design. It gradually becomes specific right on until the drafting of coordination diagrams. The general process is: First--on the basis of product diagrams as well as such factors as relevant technological conditions, production forms, development cycles, order requirements, the currently existing production technology foundation in plants, levels of industrial technique technology, and so on, specification is made of overall coordination designs and tooling selection principles. After that, on the basis of such things as product blueprints and technological factors as well as full exchange items, and so on, further designs are made of equipment coordination plans. During this, determinations are made of most tooling and standard industrial equipment as well as methods for their coordination. On this foundation, precise designations are made of specialized tooling and inspection test tooling associated with machine worked parts and turned metal parts. In conjunction with this, use is made of such forms as schematic diagrams as well as network charts, and so on, to display the manufacturing systems, subordination relationships, and partnership and coordination relationships determined on between parts tooling, assembly tooling, standardization tooling, and transitional tooling, and then coordination charts are drawn up. The information flow associated with the entire process is as shown in Fig.1. /1231

Problems existing with this type of coordination system design method:

(1) Definitions are not clear with regard to a series of closely related problems that need to be resolved.

(2) Taking the whole coordination system design work and turning it into one system makes it difficult to describe quantitatively certain inputed information--for example, plant production preparation capabilities, and so on.

(3) The process of resolving problems is a gradual process of specification and detailing. Policy making processes are confused. A great many need to be resolved relying on experience. Mathematical models cannot be formed.

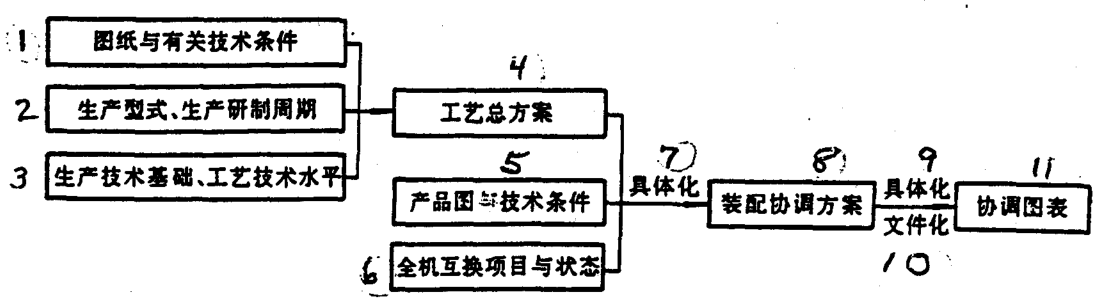

Fig.1 Tooling Coordination System Design Process

Key: (1) Blueprints and Related Technological Factors
(2) Production Types and Production Development Cycles
(3) Production Technology Foundation and Industrial Technology Level (4) Overall Industrial Technology Plan (5) Product Blueprints and Technology Factors (6) Assembly Coordination Plan (7) Specification (8) Reduction to Writing
(9) Coordination Charts and Tables

2 COMPUTER ASSISTED TOOLING COORDINATION SYSTEM DESIGN PROCESSES

When opting for the use of computers to carry out coordination system design, there is a need to take traditional coordination system design methods and carry out rational simplification and break down, making definitions associated with each part after break down clear, policy making concepts in each design phase distinct, and the use of computers for solution easy. At present, we will take aircraft tooling coordination system design work and break it down into four parts:

(1) Precise Determination of Overall Coordination Plans
Precisely determine operating methods to act as overall full exchange coordination plans.

(2) Selection of Tooling (Includes Standard Tooling)
Under a certain overall coordination plan--with regard to a certain specific coordination position--determine what assembly, inspection testing or parts tooling should be selected for use, whether or not standard tooling must be selected for use, and what type of standard tooling should be selected.

(3) Determine Coordination Relationships
With regard to a certain coordination position, determine standard tooling and tooling to be opted for in use at the position in question as well as the coordination relationships between the original bases.

(4) Drawing Up of Coordination Charts and Tables
Take the standard tooling, tooling, and original bases, as well as coordination relationships between them and use charts and tables as a form of displaying them. At this time, a draft structure chart for the coordinated position can also be displayed.

Computer assisted aircraft tooling coordination system design processes are as shown in Fig.2.

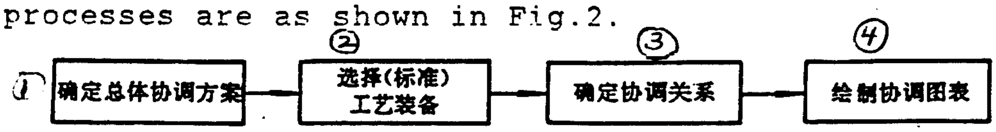

Fig.2 Computer Assisted Design Aircraft Tooling Coordination System Processes

Key: (1) Determine Overall Coordination Plan (2) Select (Standard) Tooling (3) Determine Coordination Relationships (4) Draw Up Coordination Graphs and Tables

3 DETERMINE OVERALL COORDINATION PLAN

/1232

At the present time, in the Chinese aviation industry, overall coordination plans which have been opted for are: A_1 pattern line sample plate datum hole operating method; A_2 pattern line; A_3 composite operating methods opting for the use of pattern line sample plates, datum holes, local standard samples, local surface samples, and standard gauges to carry out coordination; A_4 unitized coordination methods associated with computer assisted aircraft design and manufacture. Unitized coordination methods are often combined in use with the three previous types. They also respectively form various types of new x x x operating methods ($A_1 + A_4$, $A_2 + A_4$, $A_3 + A_4$). For example, the combined use of composite operating methods and then forms new composite ($A_3 + A_4$) [1]. These operating methods constitute the overall coordination design assembly A.

$$A = (A_1, A_2, A_3, A_4, A_1+A_4, A_2+A_4, A_3+A_4).$$

The objective of designing tooling coordination systems is--on the foundation of actual plant situations--to use the most economical means to guarantee the coordination and unification of product form and dimensional properties, and, in conjunction with that, be convenient for a certain scale of production. As a result, which overall coordination plan to select for use is determined by: B_1 aircraft speed; B_2 aircraft geometrical configuration and part geometrical dimensions; B_3 aircraft production forms; B_4 numbers of aircraft produced; B_5 aircraft development cycle; B_6 aircraft exchangability requirements; B_7 plant CAD/CAM technology levels; and, B_8 plant technology tradition. That is,

$$A_i = \Phi (B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8) \quad (1)$$

In this, $A_i \in (A_1, A_2, A_3, A_4, A_1+A_4, A_2+A_4, A_3+A_4)$

In order to reflect the influence of a certain factor with regard to a certain type of overall coordination method, according to the magnitude of the influences of this factor on the operating methods in question, a certain weighting value Q_{ij} (i=1, 2, ..., 7; j=1, 2, ..., 8) is given. For example, Q_{34} stands for the influence of aircraft production on unitized coordination methods. Therefore, equation (1) is changed to be written as

$$A_i = \varphi\,(Q_{ij}) \quad i=1, 2, \cdots, 7;\ j=1, 2, \cdots, 8 \tag{2}$$

As a result, overall coordination design determination then turns into a problem of calculation weighting values. Among the 8 factors above, B_1 - B_5 are monomial factors. The factors influence some one area in a certain type of overall coordination method. For example, when aircraft are produced in large lots, overall coordination methods should be appropriate to tooling being capable of convenient duplication, satisfying in a timely manner this production characteristic. As a result, B_3 aircraft production forms are closely related to this area with regard to overall coordination methods. Moreover, with regard to other areas associated with overall coordination methods--for example, coordination accuracy--there is no direct influence. B_6 - B_8 are composite factors. What composite factors embody is not specific influences on a certain area with regard to overall coordination methods, but is the composite embodiment of relationships with regard to certain types of overall coordination methods. Going through the analysis above and statistical analysis with regard to domestic aviation plant overall coordination methods, equation (2) is changed to become

$$A_i = Q_{i6} Q_{i7} Q_{i8} \sum_{k=1}^{5} Q_{ik} \quad i=1, 2, \cdots, 7 \tag{3}$$

During applications--with regard to a certain aircraft model--the largest weighted values A_i (i=1, 2, ..., 7) calculated out in accordance with equation (3) are nothing else than overall coordination methods recommended for selection and use.

4 SELECTION OF TOOLING (INCLUDES STANDARD TOOLING)

Selecting tooling is the concrete implementation of overall coordination designs and is basic content in aircraft tooling coordination systems. When selecting tooling--besides the basis of overall coordination designs--it is also necessary to consider structural industrial characteristics associated with coordinated positions, product production forms, production amounts, as well as the working forms associated with certain parts, and so on. The influences of these factors are relatively complicated. However, in the realization of production, industrial technology personnel have accumulated a wealth of precious experience with regard to selecting tooling. These experiences gradually accumulate in the brain, forming rules. Most of these rules are vague and unspecified qualitative rules. Only when situations with the same specific products are combined together, is it then possible to have quantitative rules. As a result, they are suited to expert system methods of solution.

/1233

Expert system methods are capable of imitating experts analyzing and handling problems. In accordance with actual situations, problems are handled in a flexible and timely manner. Expert systems include basically three parts: knowledge storage, inference engine, and man machine interface. In knowledge storage are included the experiences of multiple experts and various types of standards. Based on the user inputed actual situation, the inference engine flexibly transfers for use the rules in the knowledge base to carry out logical inference, finally arriving at conclusions.

The process for using expert system methods to select tooling is as shown in Fig.3. The definition of the problem in Fig.3 is the clear setting up of what problem the expert system must resolve, specifying the prerequisite conditions associated with problem solutions. Tooling selection expert system definitions are as shown in Fig.4.

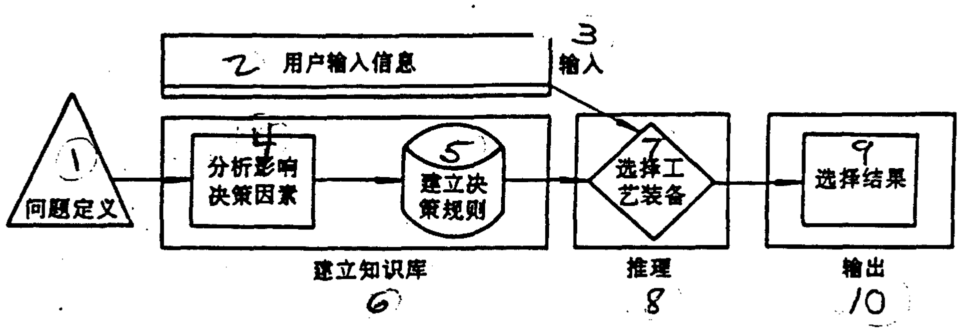

Fig.3 The Process of Using Expert System Methods to Select Tooling

Key: (1) Problem Definition (2) User Inputed Information (3) Input (4) Analysis of Factors Influencing Policy Making (5) Setting Up Policy Making Rules (6) Setting Up Knowledge Storage (7) Selecting Tooling (8) Inference (9) Selection Results (10) Output

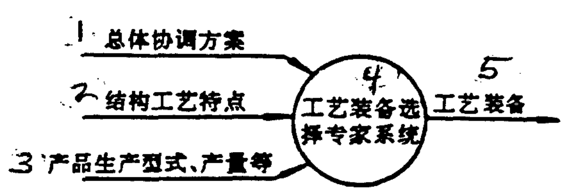

Fig.4 Tooling Selection Expert System Definition Model

Key: (1) Overall Coordination Plan (2) Structural Industrial Technique Characteristics (3) Product Production Form, Production Amounts, and So On (4) Tooling Selection Expert System (5) Tooling

Due to the knowledge level in the knowledge storage determining the level of the expert system, the form of expression of knowledge influences expert system operating efficiency. As a result, setting up the knowledge bank is the key to setting up an expert system. The collection and arrangement of knowledge are the main problems associated with the setting up of knowledge storage. Selection of tooling is primarily determined by 3 areas: (1) overall coordination plan (Z); (2) product structure industrial technique characteristics (J); and, (3) product production conditions, production form, production amounts, and so on (S). As a result,

$$K=f\ (Z,\ J,\ S) \tag{4}$$

In equation (4), $Z \in (A_1,\ A_2,\ A_3,\ A_4,\ A_1+A_4,\ A_2+A_4,\ A_3+A_4)$; $J = f_1(D, W, L)$. D stands for coordination object type. W stands for external form characteristics of coordination objects. L stands for coordination object intersection point characteristics. $S = f_2(X, P, T)$. X stands for production form. P stands for product production amount. T stands for production conditions.

At the present time, due to shortcomings in tooling selection system theory, the functional relationships f, f_1, and f_2 are still not able to precisely use mathematical forms for their expression but are only able--on the basis of these parameters (D, W, L, X, P, T)--to inspire industrial technology personnel to summarize experiences. When enumerating different combinations on the right side of equation (4), one arrives at results in accordance with experience, thereby forming a line by line empirical rule stored in the knowledge base in accordance with the IF...THEN form.

As far as tooling selection expert system knowledge bases constructed in accordance with the methods discussed above are concerned, use is made of rule forms to express them. Inference

processes are simple. Inference processes are divided into three steps: (1) check for the legality of inputed information: (2) rule matching; (3) conclusion consistency check. The process is as shown in Fig.5.

Fig.5 Expert System Tooling Selection Process

Key: (1) Input Information Legality Check (2) Rule Matching (3) Consistency Check (4) Conclusion

/1234

In Fig.3, the output process already shows expert system inference conclusions. At this time, users are capable of artificial intervention using alternate forms to correct conclusions.

5 DETERMINING COORDINATION RELATIONSHIPS

Coordination relationships indicate the coordination relationships associated with manufacture, subordination, and match ups between standard tooling, tooling, and original bases. Tooling (including standard tooling) can be divided into: component (assembly) obverse standard tooling, reverse standard tooling, part obverse standard tooling, assembly tooling, and part tooling. In sequence, these five types of tooling are taken and arranged as shown in Fig.6.

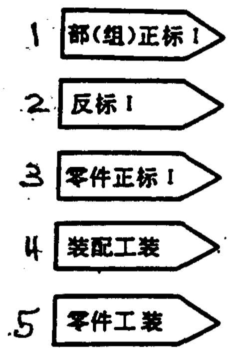

Fig.6 Tooling Level Divisions

Key: (1) Component (Assembly) Obverse Standard I (2) Reverse Standard I (3) Part Obverse Standard I (4) Assembly Tooling (5) Part Tooling

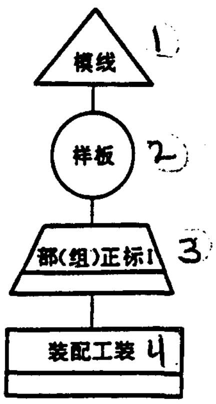

Fig.7 Basic Coordination Relationship Model (1) Pattern Line (2) Sample Plate (3) Component (Assembly) Obverse Standard I (4) Assembly Tooling

Analyzed from the angle of manufacturing processes, the coordination relationships between standard tooling and tooling are transformed into the coordination relationships between these five levels. In accordance with these five levels, it is possible to summarize basic models associated with a good number

of typical coordination relationships. Fig.7 is one of the models. It shows one type of coordination method associated with the manufacture of obverse standard tooling from original bases and the manufacture of assembly tooling from obverse standard tooling.

When determining the coordination relationships associated with a certain coordination position--after selecting the standard tooling and tooling employed by each combination of components associated with the position in question--take the toolings included in the basic models of coordination relationships and these types of standard tooling and tooling and make comparisons between them. When they are close, the coordination relationships and the coordination relationships of the basic models will also be close. After determining the coordination relationships associated with the tooling and standard tooling employed by each combination of components at a certain position, carry out a synthesis of coordination relationships in accordance with structural differentiation of composite relationships.

Now--using a certain newly developed model of domestically produced cockpit training windshield position as an example--we will make a simple discussion of the process of determining the manufacturing coordination relationships. This model of aircraft cockpit position is roughly divided into the three main sections of windshield, cockpit aperture frame, and cockpit cover. With regard to windshield assemblies, through inputed windshield characteristics--for instance, form complexity, nondigitally controlled working, and, in conjunction with that, requirements for airtightness, and so on--tooling selection expert systems then infer tooling associated with such things as windshield sample pieces, windshield assembly frames, windshield airtightness test units, windshield tempering frames, and so on, needed for the manufacture of windshields. Taking these tooling

types, comparisons are gone through with tooling types included in basic forms of coordination relationships, determining the (1) (2) and (3) shown in Fig.8 for manufacturing coordination relationships associated with each assembly tooling. In accordance with the levels shown in Fig.6, comparatively redundant parts are dropped out, synthesizing the windshield assembly manufacturing coordination relationships shown in (4) of Fig.8.

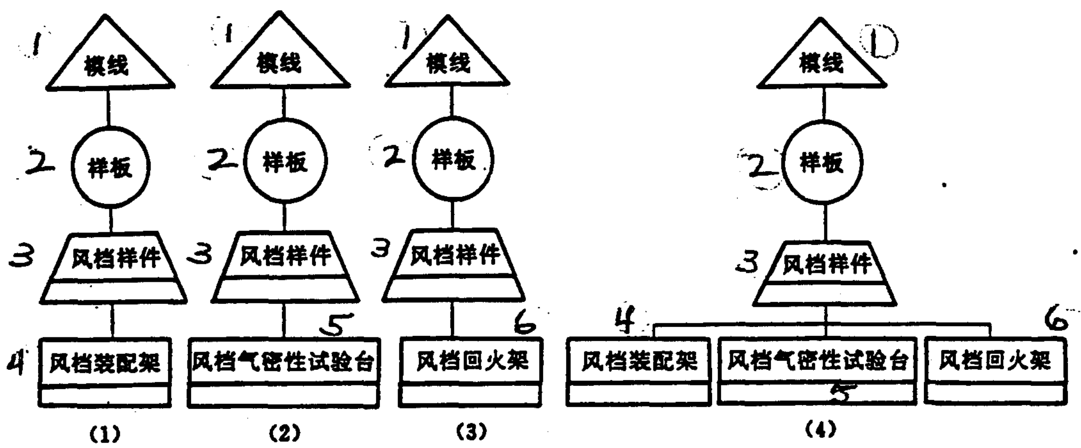

Fig.8 Schematic Diagram of Coordination Relationships Associated with Certain Models of Aircraft Training Windshield Positions

Key: (1) Pattern Line (2) Sample Plate (3) Windshield Sample Piece (4) Windshield Assembly Frame (5) Windshield Airtightness Test Unit (6) Windshield Tempering Frame

6 DRAWING UP COORDINATION CHARTS AND TABLES

Drawing up coordination charts and tables is a process of representing coordination relationships between tooling (including standard tooling) using line and block charts and linear figures. As a result, in terms of form, a coordination chart is nothing else than an ordered collection in two

dimensional space with explanatory text of a number of line and block charts and straight lines, that is $TB=[BT, ZX, WZ]_{s=1}^{n}$. In this, TB stands for the coordination charts. BT stands for standard line and block charts. ZX stands for the connecting lines between standard chart blocks. And, WZ stands for some explanatory text. Standard chart blocks are determined by the standard chart block symbol N and the standard chart block position point (x_0, y_0), that is

$$BT = (N, x_0, y_0)$$

The straight lines between standard chart blocks are determined by the coordinates of the two end points (x_1, y_2), (x_2, y_2), that is

$$ZX = (x_1, y_1, x_2, y_2)$$

Explanatory text is determined by the text code M, the writing ratio L, and the writing location (x_3, y_3), that is

$$WZ = (M, L, x_3, y_3)$$

As a result, combined mathematical models of coordination charts and tables are

$$TB=[N, x_0, y_0, x_1, y_1, x_2, y_2, M, L, x_3, y_3]_{s=1}^{n}$$

7 CONCLUDING REMARKS

Opting for the use of methods discussed above, certain aviation plants in China developed a computer aided design aircraft tooling coordination system. This system possesses such functions as coordination system automatic design, editing of coordination charts and tables, coordination accuracy calculations, tooling work time cost calculations, and so on. As

far as its broad application to production is concerned, results are good. This clearly shows that computer aided aircraft tooling coordination design has very important significance for raising coordination system design work efficiencies and design quality, shortening aircraft production preparation cycles, and promoting the computer management of industrial technology documents.

REFERENCES

1 袁自强．从两机研制浅谈新综合工作法．航空制造工程，1992；(3):

2 程宝蕖，崔赞斌．飞机制造协调技术．北京：国防工业出版社，1990:

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION	MICROFICHE
B085 DIA/RTS-2FI	1
C509 BALLOC509 BALLISTIC RES LAB	1
C510 R&T LABS/AVEADCOM	1
C513 ARRADCOM	1
C535 AVRADCOM/TSARCOM	1
C539 TRASANA	1
Q592 FSTC	4
Q619 MSIC REDSTONE	1
Q008 NTIC	1
Q043 AFMIC-IS	1
E404 AEDC/DOF	1
E410 AFDTC/IN	1
E429 SD/IND	1
P005 DOE/ISA/DDI	1
1051 AFIT/LDE	1
P090 NSA/CDB	1

Microfiche Nbr: FTD95C000744
NAIC-ID(RS)T-0375-95